A novel Integrated VMAT/IMRT technique for the treatment of non-small cell lung cancer

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Lung cancer has been the first killer of cancer in China.
Background

- 3D-CRT has proved to be effective in NSCLC.
- Intensity-modulated radiotherapy (IMRT)
  - reduced the volume of normal lung receiving low dose
  - longer treatment time and more MUs
- Volumetric-modulated radiotherapy (VMAT)
  - shorter treatment time and fewer MUs
  - larger $V_{5}$ and $V_{10}$ of lung

Patel RR, Mehta M. Curr Oncol Rep 2002
Hall EJ. Int J Radiat Oncol Biol Phys 2006
Purpose

We developed a novel technique to treat NSCLC.
Methods and Materials

patients’ characteristic

- Seventeen NSCLC patients
- Age:
  - range: 26-84
  - median: 67
- Histology:
  - Adenocarcinoma: 4
  - Sqamouscarcinoma: 7
  - Not otherwise specified (NOS): 6
- PTV:
  - Range: 41.9-453.8 cm³
  - mean: 199.3 cm³
Methods and Materials

CT体位固定—扫描层厚3 mm
Methods and Materials

Delineation of target volumes and critical structures

- **GTV**: gross tumor and lymph nodes involved (>1 cm on CT)
- **CTV**: GTV plus a 6- to 8- mm margin
  - Adenocarcinoma: 8 mm
  - Squamous cell carcinoma: 6 mm
  - Not otherwise specified (NOS): 8 mm
- **PTV**: CTV plus margin
  - **Axial**: 5 mm
  - **Cranial-caudal**: 10 mm
- **Normal lung**: double lungs minus PTV
- **Spinal cord and esophagus**: from 2 cm above the superior extent of the PTV to 2 cm below the inferior extent of the PTV
Methods and Materials

**Treatment planning objectives**

- **Prescription:** *60 Gy/30 fractions*
- **Target:**
  - $D_{98}\% > 95\%$ prescription dose;
  - $D_{2}\% < 110\%$ prescription dose
- **OARs:**
  - Normal lung
    - $V_5 < 60\%$; $V_{10} < 40\%$
    - $V_{20} < 30\%$; $V_{30} < 20\%$
    - *Mean dose* $< 16$ Gy
  - Spinal cord ($0.03 \text{ cm}^3$) $< 50$ Gy
  - Esophagus ($0.03 \text{ cm}^3$) $< 60$ Gy

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RTOG 1106: Randomized phase II trial of individualized adaptive radiotherapy in locally advanced non-small cell lung cancer (NSCLC)

Methods and Materials

Treatment planning

- IMRT
- Integrated
- VMAT

5-fields IMRT (BAO)
2 partial arcs VMAT (5-fields IMRT base plan)
2 partial arcs VMAT

The plans were normalized to cover 95% of the PTV with 100% of the prescribed dose.
Methods and Materials

Plan evaluation

- **Target evaluation:**
  - $D_{98\%}$ (minimal dose delivered to the 98% of the target volume)
  - $D_{2\%}$ (maximum dose delivered to the 2% of the target volume)
  - CN (conformation number)
  - HI (homogeneity index)

- **OARs evaluation:**
  - Normal lung: $V_5$, $V_{10}$, $V_{20}$, $V_{30}$, MLD
  - Spinal cord: maximum dose (0.03 cm³)
  - Esophagus: maximum dose (0.03 cm³) and mean dose
  - Heart: $V_{40}$, $V_{60}$, mean dose

- Treatment delivery time and MUs

RTOG 1106: Randomized phase II trial of individualized adaptive radiotherapy in locally advanced non-small cell lung cancer (NSCLC)
## Results

### Target

<table>
<thead>
<tr>
<th>PTV</th>
<th>IMRT mean ± SD</th>
<th>VMAT mean ± SD</th>
<th>Integrated mean ± SD</th>
<th>IMRT vs VMAT p value</th>
<th>IMRT vs Integrated p value</th>
<th>VMAT vs Integrated p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>D$_{98}%$ (Gy)</td>
<td>58.3 ± 0.5</td>
<td>58.4 ± 4.1</td>
<td>58.8 ± 2.1</td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>D$_{2}%$ (Gy)</td>
<td>68.8 ± 21.9</td>
<td>67.4 ± 21.0</td>
<td>64.9 ± 9.6</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>CN</td>
<td>0.7 ± 0.1</td>
<td>0.8 ± 0.1</td>
<td>0.9 ± 0.1</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>HI (%)</td>
<td>16.1 ± 3.6</td>
<td>13.9 ± 3.4</td>
<td>9.9 ± 1.4</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>
## Results

### OARs

<table>
<thead>
<tr>
<th></th>
<th>IMRT mean ± SD</th>
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<tbody>
<tr>
<td><strong>Normal lung</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$D_{2%}$ (Gy)</td>
<td>48.7 ± 7.9</td>
<td>45.3 ± 8.1</td>
<td>44.7 ± 7.9</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>$*V_{30}$ (%)</td>
<td>9.2 ± 4.2</td>
<td>8.9 ± 4.9</td>
<td>8.4 ± 4.4</td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>$*V_{20}$ (%)</td>
<td>14.5 ± 6.7</td>
<td>14.6 ± 7.3</td>
<td>14.6 ± 6.9</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>$*V_{10}$ (%)</td>
<td>21.5 ± 10.3</td>
<td>24.9 ± 12.3</td>
<td>23.5 ± 11.8</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>$*V_{5}$ (%)</td>
<td>34.1 ± 15.8</td>
<td>42.9 ± 19.1</td>
<td>38.7 ± 18.1</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean (Gy)</td>
<td>8.1 ± 3.3</td>
<td>8.7 ± 3.7</td>
<td>8.3 ± 3.5</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>Spinal cord</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$D_{\text{max}}$(Gy)</td>
<td>36.4 ± 13.4</td>
<td>30.6 ± 10.4</td>
<td>31.5 ± 10.4</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&gt;0.05</td>
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</table>
# Results

## OARs

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<td><strong>Esophagus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$D_{\text{max}}$ (Gy)</td>
<td>51.2 ± 16.1</td>
<td>51.8 ± 14.9</td>
<td>50.6 ± 13.9</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean (Gy)</td>
<td>14.0 ± 10.3</td>
<td>15.2 ± 9.8</td>
<td>14.6 ± 9.8</td>
<td>&lt;0.05</td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>Heart</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$D_{2%}$ (Gy)</td>
<td>27.5 ± 27.1</td>
<td>24.1 ± 23.1</td>
<td>24.4 ± 23.3</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Mean (Gy)</td>
<td>7.1 ± 8.9</td>
<td>6.4 ± 8.0</td>
<td>6.5 ± 8.0</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>*$V_{60}$ (%)</td>
<td>1.7 ± 3.9</td>
<td>1.2 ± 3.4</td>
<td>1.2 ± 3.4</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>*$V_{40}$ (%)</td>
<td>5.2 ± 8.7</td>
<td>2.9 ± 6.9</td>
<td>3.2 ± 7.1</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>
Results

IMRT: solid lines  VMAT: dashed lines  Integrated: dotted lines

Normal Lung

Esophagus

Heart

Spinal Cord

PTV
Results

A: IMRT	B: VMAT	C: Integrated
## Results

### Delivery time and MUs

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<th>VMAT vs Integrated p value</th>
</tr>
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<tr>
<td><strong>Delivery time (s)</strong></td>
<td>280 ± 52</td>
<td>114 ± 7</td>
<td>327 ± 39</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>MU</strong></td>
<td>933 ± 222</td>
<td>512 ± 35</td>
<td>737 ± 98</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>
Discussions

- Chan et al reported a Hybrid-RapidArc technique utilizing two arcs with additional static conformal fields
  - produce lower $V_5$, $V_{10}$ and MLD of normal lung
  - *fail to meet the challenge cases (highly irregular PTV)*

- Martin et al reported a IMRT&ARC technique consisted of 4-field IMRT in conjunction with a conformal arc.
  - Improve the therapeutic ratio
  - *forward planning for conformal arc as well as manual IMRT beam arrangement*

Conclusions

- Compared with IMRT
  - *Integrated VMAT/IMRT significantly improved both the target dose conformity and homogeneity.*
  - Integrated VMAT/IMRT significantly reduced the irradiated volume of the OARs and normal tissue receiving medium to high dose and MUs.

- Compared with VMAT
  - Integrated VMAT/IMRT significantly improved both the target dose conformity and homogeneity.
  - *Integrated VMAT/IMRT reduced the volume of normal lung receiving dose higher than 10 Gy, 5 Gy and MLD significantly*
谢谢
2014
马到成功
HAPPY NEW YEAR